Center for Independent Experts (CIE) Independent Peer Review of the

# Central Valley Chinook Life Cycle Model

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## Executive Summary:

The NOAA Fisheries Southwest Fisheries Science Center (SWFSC) is developing a Central Valley Chinook Life Cycle Model (LCM) to provide scientific input to a biological opinion on the effects of the operations of the state and federal Central Valley water projects on listed anadromous fishes. The LCM is a work in progress, with the current version tailored for winter Chinook, and through the Center for Independent Experts (CIE), the SWFSC convened an expert panel to provide feedback and advice, as recommended by an earlier review (Rose et al. 2011). Rather than a panel report, each member of the panel has written individual reviews; this is mine.

In summary, my findings and main recommendations for the model are:

The SWFCS is developing a complex Bayesian model of the salmon life cycle that links to existing models of flow in the Sacramento River and the Delta, plus a river temperature model and an ocean model. The SWFSC is using state-of-the-art methods for fitting the model to data, and the scale and representation of the river in the model are appropriate for a life cycle model, but can be improved by dividing the river into two habitats at Red Bluff. The model generally incorporates the best available science and methods for winter Chinook, except for the method for estimating habitat capacity, and so far lacks a necessary method to assess the effects of hatchery fish on the productivity of the winter Chinook population. Adapting the model for other runs of Chinook, including the listed Central Valley Spring Chinook, will require more work.

My main recommendations are:

1. Divide the representation of the river in the model into two sections, at Red Bluff.
2. Account for the effects of hatchery fish on the productivity of Chinook populations.
3. Develop Bayesian Network models for the habitat capacity of the river, using the opinions of field biologists as well as other information to populate the conditional probability tables. Use this in place of the depth, velocity, roughness method. As an alternative, simply use the opinion of field biologists who have spent time in the river observing habitat use by juvenile Chinook.

Because the model is a work in progress, it is not possible to say whether the completed model will represent the best available science, as I understand the term to be used in the Endangered Species Act. However, if these recommendations are successfully implemented, then likely it will.

**Background:**

This is a review of a model under development, the Central Valley Chinook Life Cycle Model (LCM), which is intended to provide useful guidance for a biological opinion that NMFS will soon prepare on the effects of operations of the state and federal water projects on listed anadromous fish in the Sacramento and San Joaquin rivers. Such biological opinions must be based on the "best available science." The version of the model under review is specifically for winter Chinook, which are listed as endangered under the federal Endangered Species Act. The heart of the material under review was presented to a review panel at a workshop on November 5 and 6, 2015.

**Description of the Individual Reviewer's Role in the Review Activities:**

Before the review panel workshop, I read the material provided, and reviewed other relevant materials on Chinook salmon, and then participated in the workshop. At the review panel, the panel was presented two superficially similar but different models: Version 1, a simulation model that is described by Hendrix et al. (2014), and Version 1.1, an estimation model that is based on the same conceptual model as Version 1. Work on Version 2 is in progress. Version 1.1 is a complex estimation model that can be fit to data only by use of advanced methods such as Markov Chain Monte Carlo (MCMC), in this case adaptive MCMC. I am not expert in the use of these methods, although I have some understanding of them and am persuaded of their value. Therefore, my review deals mainly with biological matters and the representation of habitats in the model.

**Summary of Findings:**

**ToR 1):**

Is the model useful for informing NMFS of the effects of water operations and prescribed RPA actions on salmonids at various life stages and at the population level?

a) What are the strengths and weaknesses of the model?
b) Are key parameters and performance measures captured in the model? If not, what other parameters and performance measures should be included?
c) Can the model be applied to address the multiple timescales associated with RPA decisions and operations?
d) What are the technical constraints to the implementation of the model and the feasibility to address them (e.g., transparency of the model, data sets availability, model parameter uncertainties and sensitivities, etc.)?

*Is the model useful for informing NMFS of the effects of water operations and prescribed RPA actions on salmonids at various life stages and at the population level?*

George Box famously said that "all models are wrong, but some are useful." However, whether a model is useful depends not just on the model, but also on the user of the model. Someone who understands both a system and a model of it may be able to get good use from even a poor model, whereas some not as skilled or knowledgeable would get nonsense. That is, one needs to know just how the model is wrong, and how that matters for the system of interest and the question at hand. This is particularly a problem for models like Version 1.1 of the Life Cycle Model (LCM), which links together a set of distinct models, deals with a complex system about which much is poorly understood, and uses fitting methods that require expertise for good results. No one person can be expected to have the necessary skills and knowledge, so the upshot is that only a cooperative group can be expected to do useful analyses with the LCM, or to assess analyses done by others.

The LCM is still a work in progress, as noted above, but I think that, with modifications described below, it is potentially useful for informing NMFS of the effects of some water operations and RPAs on winter Chinook at the population level. However, because of the very low survival of naturally produced winter Chinook eggs or alvins in the last two summers, the proportion of hatchery fish in the run presumably will be much higher in the near future. This will likely affect the behavior of the fish productivity of the population (e.g., Chilcote et al. 2011; Christie et al. 2012; Christie et al. 2014), and erode the utility of models based on existing data for assessing the effects of project operations.

Moreover, the utility of the model will depend on the particular questions being asked. For example, I expect that the model would do better at answering questions such as the relative harm at the population level from incidental take at the export facilities and incidental take in the ocean fishery, than about the benefits of specific RPAs. In particular, I expect that there will be attempts to use the model to fine tune the operation of the export facilities, which will seem possible because of the short time step in the particle tracking model, but it will be easy to ask too much of the model for that purpose.

I am less optimistic that Version 2 would be useful for spring and fall Chinook, which have more complex juvenile life history patterns than winter Chinook, without further modification.

*a) What are the strengths and weaknesses of the model?*

Strengths:

Version 1.1 is being fit to data with up-to-date MCMC methods that allow the model to be more complex than would otherwise be the case. These methods are key to the model's utility, although they are also very difficult and time consuming to implement. The alternative of constructing a life cycle simulation model is easier, but such a model would be too complex to be a useful thought experiment, and would not support reliable assessments of future operations or RPAs.

It is well known that models should be as simple as possible, but no simpler. I think that the geographical representation of habitat for winter Chinook in the LCM (Figure 1 in Hendrix et al. (2014) is not far from optimal, but can be improved by dividing the Sacramento River at Red Bluff into a primarily gravel bed, moderate gradient reach upstream, and a predominately sand bed, low gradient reach below. This should work well, since monitoring at the Red Bluff Diversion Dam provides some of the best data on juvenile Chinook in the Sacramento River, and these data should be used in fitting the model. As it is, a ~ 100 km reach of spawning/rearing habitat and a ~250 km reach of rearing/migratory habitat are lumped together. This makes it impossible to distinguish what I have called fry migrants to low gradient streams and fingerling migrants (Williams 2012). Moreover, distinguishing these habitats allows for a test of a concept applied in the model, discussed below. The downstream end of the rearing/migratory habitat at the boundary of the legal Delta in geographical representation seems close enough to the monitoring station at Knights Landing that data collected there can be used for that boundary.

Weaknesses:

<u>Migration:</u>

The treatment of juvenile migration in the LCM seems to me a weakness. In the LCM, a small, fixed fraction of winter-run fry migrate directly to tidal habitat, and other fry migrate in response to fish density, following the example of Greene and Beeche's (2004) model of Chinook in the Skagit River. This seems a bit of a conceptual patchwork. There is evidence for density dependent migration on the Skagit River (Green and Beeche 2004; Zimmerman et al. 2015), and the idea the fry migrations are driven by fish density or limited habitat capacity in the stream has a long history, but, so does the idea that the migration is deliberate or volitional (e.g., Healy 1991: 332-333), and I think that overall the evidence better supports the concept that the timing of migration is largely volitional. As summarized in Williams (2006:69), and elaborated in Williams (2012):

> There is good evidence for genetic variation in the propensity of ocean-type Chinook to migrate as fry (Carl and Healey 1984), although year to year variation in the proportion of fry and fingerling migrants in some Central Valley rivers, described below, shows that environmental factors also matter. It seems likely that there is some genetically influenced but variable threshold for fish to migrate as fry, analogous to the threshold for smolting in the Thorpe et al. (1998) life history model for Atlantic salmon, discussed in Ch. 1.

It is clear from monitoring in the Central Valley that the majority of juveniles of all runs except late fall Chinook migrate downstream as fry, either to low gradient streams, the Delta, or the bays. For example, Figure 6 from Poytress et al. (2014), partially copied below, show that a large majority of juvenile winter Chinook pass Red Bluff as fry before November, and larger juveniles do not appear in the catch before late October.

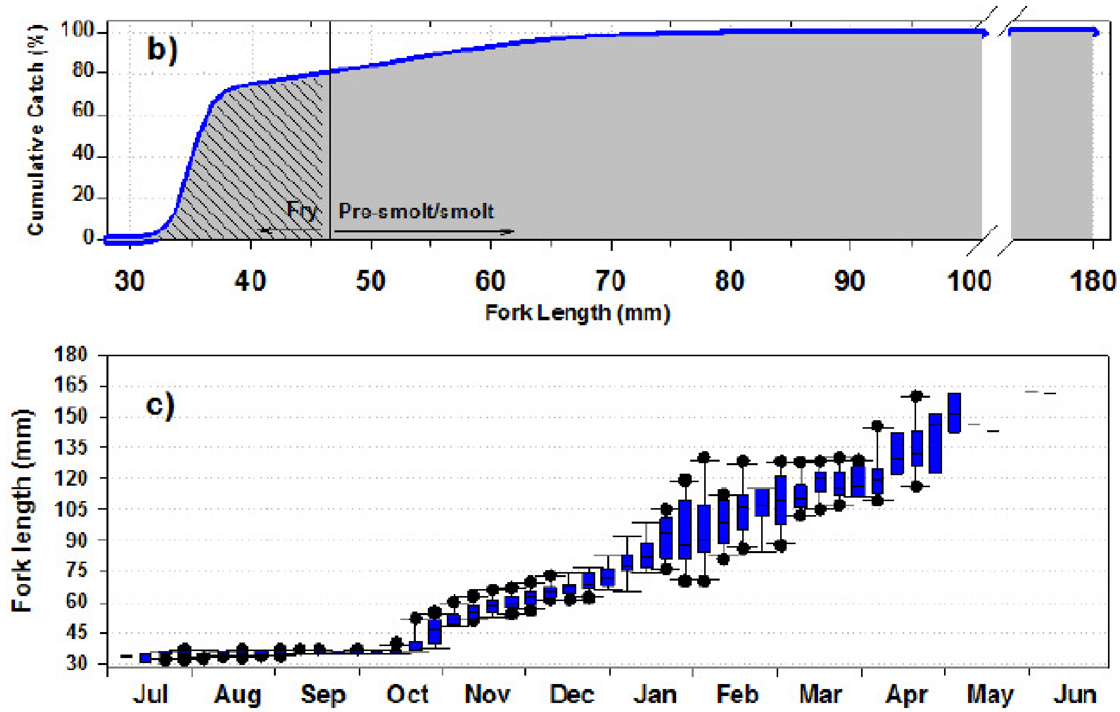
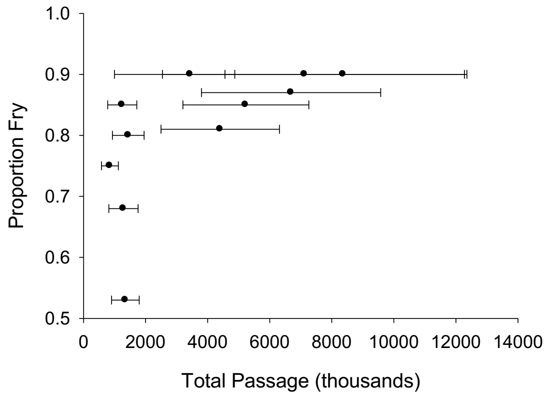
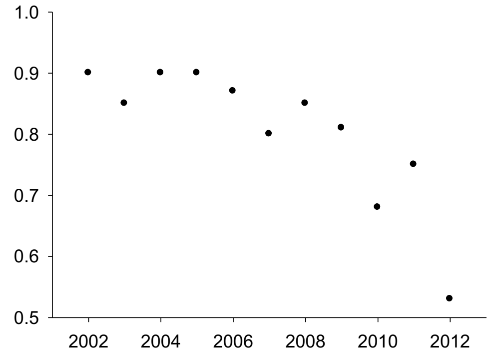


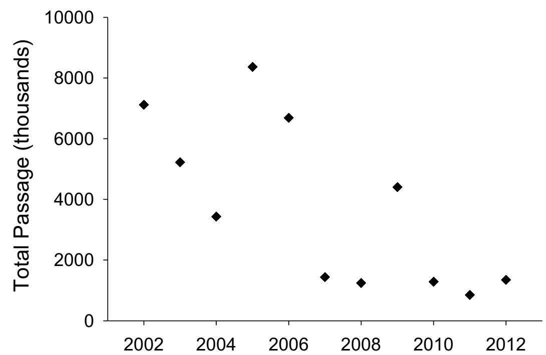

Figure 6 from Poytress et al. (2014). Winter Chinook fork length (a) capture proportions, (b) cumulative capture size curve, and (c) average weekly median boxplots for winter Chinook sampled by rotary traps at the Red Bluff Diversion Dam (RBDD) between July 2002 and June 2013.

The LCM uses two categories of juveniles, fry and smolts, but the implicit definitions of these terms are different from the usual meanings. As I understand it, in the model smolts are implicitly defined by a propensity to migrate, and the proportion of rearing juveniles that migrate (i.e., turn into smolts) is a function of the calendar month. So, the larger juveniles passing the RBDD in winter would be the smolts in the LCM. However, in the LCM, it seems that the majority of the fry passing the RBDD are not volitional migrants, but rather are forced to migrate, presumably by competition for space upstream.

Table 5c in Poytress et al. (2014) gives data on the estimated total passage of juvenile winter run and the proportion fry (< 46 mm) for brood years 2002-2012, so I plotted the percentage fry over total passage to see if the percentage fry increases with total passage. If it does, the relationship has a sharp threshold at about two million. However, the percentage fry also decreases over time more smoothly than does the total passage (for example, passage was similar in the last three years), which suggests that something else is involved.






Data from Table 5c in Poytress et al. (2014); bars show 95% confidence intervals.

During the panel presentation, Noble Hendrix noted that with low flows, juveniles are more likely to migrate and less likely to survive (Summary Report, p. 12). However, with 2010 as an exception, the Poytress et al. (2014) data do not seem to support this. Instead, the proportion of fry migrants increases with discharge.

(Discharge data from USGS)

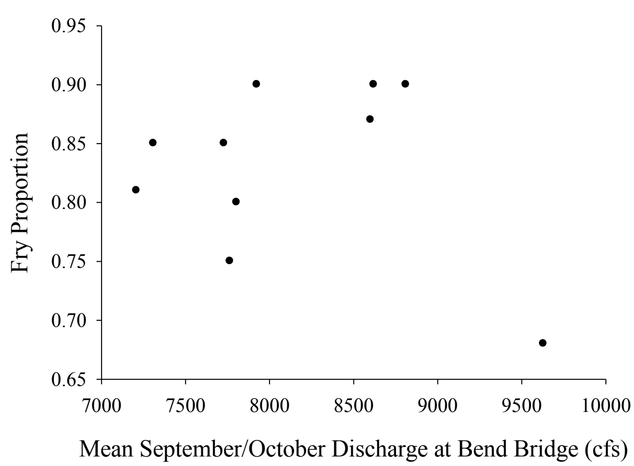
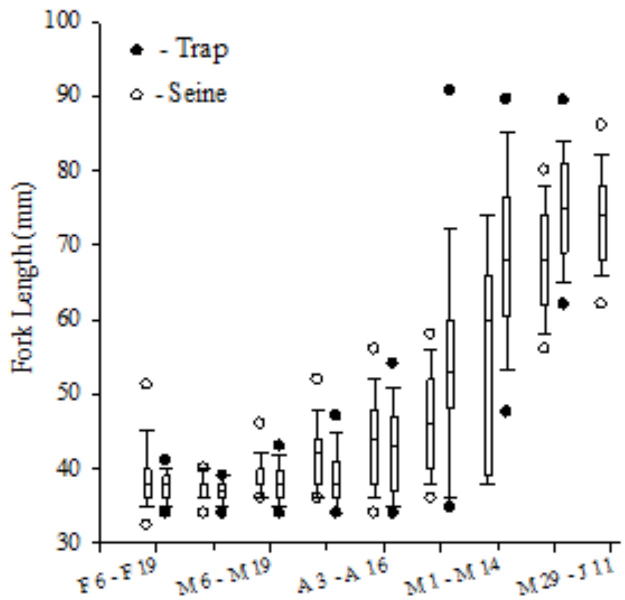


Figure 9 from Williams (2001). Size distributions of juvenile Chinook salmon captured in the lower American River in screw traps (box plots with closed circles) and seines (box plots with open circles) in 1995. Sample periods are two weeks. Data from CDFG.




Interpreting the pattern in Figure 6 from Poytress et al. (2014) is complicated by the lack of monitoring of juveniles in rearing habitat upstream from Red Bluff. That is, some juveniles could be establishing territories shortly after emerging, so that others cannot, and migrate instead. By this view, these residents would be the larger migrants sampled later in the winter. There are few of these, which implies that there is little rearing habitat above Red Bluff, assuming density-dependent migration. However, there are data from American River, a major Sacramento River tributary, that address this issue for fall Chinook. Juvenile fall Chinook were sampled with a rotary trap near the downstream end of the spawning area, and also by seining further upstream. Data for 1995 were summarized in Figure 9 of Williams (2001), and show that the fish captured by the trap and by seines were about the same size, mostly < 40 mm, until early April. Later in the spring, the fish captured by the traps were somewhat larger than those captured by seine. That is, fish did not seem to be taking up residency until sometime in mid-March, by which time most had left the river. This does not seem consistent with density-dependent migration.

Does all this matter? Hendrix et al. (2014) state at p. 3 that “State transitions can be flexibly described by an extension of the Beverton-Holt stock-recruitment relationship that allows (but does not require) individuals exceeding the capacity of a habitat to move downstream, rather than die in that habitat (Greene and Beechie 2004).” This is true, but if indeed juvenile Chinook are genetically predisposed to different migratory behaviors, then the LCM may mislead, even if output from the LCM can match observed behavior. In particular, the LCM may mislead about "the quantity and quality of rearing and migratory habitat [which] are viewed as key drivers of reproduction, survival, and migration of freshwater life stages" (Hendrix et al. 2014:5). However, since juvenile winter Chinook seem to arrive at the Delta at about the same time, the issues discussed above may matter less for assessing project operations in the Delta on winter Chinook than on spring or fall Chinook.

<u>Habitat capacity:</u>

A related weakness in the LCM is the PHABSIM-like approach to estimating habitat capacity in the river, described in Hendrix et al. (2014), in which habitat capacity is a function of depth, velocity, and an index of channel roughness, as estimated by the HEC-RAS model. There is little evidence that PHABSIM and similar models can predict where juvenile fish will be (Williams 2011, Appendix A), even though the models incorporate empirical distributions of fish over the habitat variables. One reason for this failure is poor estimates of velocity, even for 2-D models using a much finer spatial scale than the 1-D HEC-RAS model of the Sacramento River (e.g., Guay et al. 2001; Gard 2010). (I have been told that 2-D hydraulic models have improved considerably over the last few years, but have not yet seen data demonstrating this). Another reason is that fish select habitat based on other factors, such as the available food supply, as well as the traditional microhabitat variables. Finally, HEC-RAS operates at a much coarser spatial scale than the spatial scales at which fish select microhabitat, the scale at which depth, velocity, and substrate are typically used.

As applied in the LCM, habitat capacity is designated as high or low quality, according to criteria given in Table 1 of Hendrix et al. (2014), who note that "Ranges of high and low habitat quality were based on published studies of habitat use by Chinook salmon fry across their range and examination of data collected by USFWS within the Sacramento- San Joaquin Delta and San Francisco Bay." The criteria strike me as misleading, especially for mainstem habitats that include riffles, runs, and pools, in which juvenile salmon often behave differently, and because "fry" as used in Hendrix et al. (2014) includes a considerable range of sizes, which typically are reported to select different microhabitats. In particular, the velocity criterion for mainstem habitat seems low, compared to literature values, which may result from taking values from "studies of habitat use by Chinook fry" that used a lower upper size limit for fry, such as the 46 mm used by Poytress et al. (2014). I do not have data from observations of habitat use by juvenile Chinook at hand, but a MS thesis by Terry Jackson from ~ 1992 has such data for the American River; it should be available through Oregon State University.

For a specific example of the criteria being misleading, Steve Lindley, who is heading the modeling effort, may recall that when the Central Valley Technical Recovery Team held a workshop to hear presentations on Central Valley Chinook and their habitats, Doug Killam, a CDFW biologist, showed impressive underwater video of a run in the Sacramento River near Redding that looked rather like a giant hatchery runway. Yet, as I remember the video, under the

Table 1 criteria this would be classified as poor habitat, for being too deep, lacking roughness, and probably for flowing too rapidly.

In my opinion, it will not be possible to develop useful estimates of the habitat quality in the river within the LCM. This is an exercise in environmental flow assessment, which remains a challenging problem with no simple solution. A better approach would be linking another model to the LCM. Steve Lindley mentioned a dynamic energy budget model as one possibility, but this may require better hydraulic modeling than will be available for some time, and is not expected to be ready for the Biological Opinion. My hunch is that the best approach, especially in the near term, would be to develop Bayesian Network models for the river. Such models have been used for environmental flow assessment, particularly in Australia (e.g., Stewart-Koster et al. 2010; Chan et al. 2012), and have the virtue of being transparent to stakeholders while making the uncertainty in the assessment explicit. If time does not allow this, using the expert opinion of field biologists such as Doug Killam, who have spent a lot of time in the river, would be an alternative.

The problems discussed so far may matter less for Winter Chinook than for other runs, because winter Chinook tend to enter the lower reaches of the Sacramento and the Delta at about the same, so the distinction between the moderate gradient, gravel bed reach and the low gradient, sand bed reach may not be less important for them, and for assessing diversions and RPAs in the Delta. Because the population is so small, erroneous estimates of habitat capacity should not be a major problem, either. However, with the current approach, estimates of the habitat capacity of the river should be regarded with great caution.

<u>Hatchery influence:</u>

The model does not yet address the issue of hatchery fish. This is a significant weakness. Given the poor survival in hyporheic habitat in the last two years, the proportion of adults that are hatchery fish will increase sharply in the coming years, with serious implications for the productivity of the population (Chilcote et al. 2011; Christie et al. 2012; 2014). This is a significant weakness. Reducing the alpha parameter in the Beverton-Holt relationship as a function of hatchery influence may be a way to address it. Chrisite et al. (2014) reported that:

> Combining 51 estimates from six studies on four salmon species, we found that (i) early-generation hatchery fish averaged only half the reproductive success of their wild-origin counterparts when spawning in the wild, (ii) the reduction in reproductive success was more severe for males than for females, and (iii) all species showed reduced fitness due to hatchery rearing.

*b) Are key parameters and performance measures captured in the model? If not, what other parameters and performance measures should be included?*

Most but not all are. Key performance measures for the model will be estimates of uncertainty in the model results, and how well the model results compare with the historical record. The LCM does attempt to provide such estimates of uncertainty, which is a giant step forward, but currently Version 1.1 assumes only observation error. Modifying the model to deal also with process error will be a major improvement. Also, as noted above, the model does not currently deal with hatchery influence.

Other key performance measures, especially for spring and fall Chinook, include how well the model estimates the contributions to the spawning population of different life history patterns. Unfortunately, there are only a few data on the latter question (e.g., Miller et al. 2010; Sturrock et al. 2015), so obtaining more such data should have high priority.

I am not sure how to answer the question regarding parameters. For example, the model simulates habitat capacity, so there is an associated parameter, but I question the way that this is done.

*c) Can the model be applied to address the multiple timescales associated with RPA decisions and operations?*

The LCM can be applied to multiple timescales associated with RPA decisions and operations in the Delta, because the particle tracking model can work with short timescales. In other parts of the system, for example the river, the time steps are limited by CALSIM, and so are the timescales that can be addressed. This is discussed further in answer to ToR 2.

*d) What are the technical constraints to the implementation of the model and the feasibility to address them (e.g., transparency of the model, data sets availability, model parameter uncertainties and sensitivities, etc.)?*

The methods used to fit the model will be transparent only to people with good understanding of adaptive MCMC; to others, it will seem like some kind of magic (black or white, depending on how well they like the results). I do not see a way around this.

As mentioned above, there is a shortage of good data on the basic biology and behavior of naturally produced Chinook in the Central Valley. Problems with some of the existing data sets, such as the USFWS seine data, are discussed in Williams (2006), and many of the recommendations for monitoring and research in Williams (2006) and Williams (2009) still apply. In particular, determining the juvenile life histories of fish that survive until harvest or reproduction using microchemical and microstructural analyses of otoliths should be given high priority.

Another issue is whether migratory behavior is self-reinforcing, which could affect the utility of estimates of migration rates developed from acoustic tagged hatchery fish. My thinking on this has been influenced by a largely ignored paper by Ewing et al. (2001) regarding spring Chinook in the Rogue River, and by coded-wire tag data from the Central Valley. Over 100 times as many coded-tagged juvenile fall Chinook released at Coleman Hatchery had been captured in the Chipps Island trawl than were recovered at the export facilities (Williams 2012, Table 1). However, tagged juveniles released in the Delta apparently are much more likely to be recovered at the export facilities. The simplest explanation of this seems to be that juvenile Chinook migrating down the Sacramento River developed migratory behavior that kept them out of the south Delta. This could also explain why few Butte Creek spring Chinook that were tagged as they migrated as fry out of the mountains were recovered at the export facilities, even though almost all tagged adult fish recovered in Butte Creek had been tagged as fry (Williams 2006:32). If migratory behavior is self-reinforcing, it seems like something that should be accounted for in the model, although its importance may vary across runs. Self-reinforcing migratory behavior would also raise questions about the utility of studies using hatchery juveniles with acoustic tags; results from such studies are used in the LCM.

**ToR 2):**
*Has NMFS effectively linked multiple specific models to represent the whole life cycle to inform NMFS in determining the effects of water operations and prescribed RPA actions on salmonids at the population level?*

Since Version 1.1 is still a work in progress, there is not a firm answer to this question, but NMFS is making good progress toward linking various models, such as the particle tracking model and the ocean model, to make an informative whole. I am less sanguine about the CALSIM and HEC-RAS models used for the riverine part of the system, and how useful the particle tracking model will be will depend on the modeled "behavior" of the particles. However, I do not have practical suggestions for alternatives.

CALSIM is an operations model that runs on a monthly time step. CALSIM does not model the passage or routing of water down the river, which is unnecessary for monthly time steps, but does seem necessary for modeling the effects of some contemplated projects, particularly the large tunnels that are proposed to move Sacramento River water across the Delta. Similarly, it is not suitable for assessing the effects of short-term changes in releases from Shasta Dam that de-water fall Chinook redds. The model includes a work-around for when water will flow into the Yolo Bypass, but this will not work well if the duration or total flow into the by-pass matters. One obvious problem concerns the timing of the flow threshold for migration into the Delta described by del Rosario et al. (2013). Modelers for the Bureau of Reclamation and the Dept. of Water Resources have long been aware that the monthly time step is a problem for biological analyses, so I suspect that trying to shorten the time step substantially is difficult, or else it would have been done already.

Another concern with CALSIM is that traditionally, analyses have been done using the historical hydrological record. This raises two problems. One is that operational rules can be optimized for the historical time series, whereas future time series would be different even without climate change. The other is climate change, which will increasingly make the historical time series misleading. This makes some kind of synthetic hydrology seem useful.

HEC-RAS is a one dimensional hydraulic model that is intended primarily to predict stage at transects for analyzing flood hazards. Doubtless it does this well. However, for purposes of the LCM, some method for distributing velocity across the transects is necessary, and apparently this is done with an approximation using depth and roughness that is not really physically based. As applied to the Sacramento River, the transects are close together for flood control analyses, but still far apart at the spatial scales that matter to small fish. Accordingly, I am not optimistic that estimates of depth, velocity and roughness in patches as defined in the LCM will be very good.

**ToR 3):**

*Is the model framework suitable for winter-run, spring-run, and fall-run and can the framework be adapted for other species of Pacific salmonids?*

Because winter-Chinook tend to enter the Delta at about the same time (del Rosario et al. 2013, Figure 3), the current model framework may be easier to apply to winter-run, and perhaps late fall-run, than to fall or spring Chinook that migrate over a longer period and exhibit more diverse juvenile life histories. For fall and spring Chinook, the question whether fry migration is volitional or density-dependent will be more important. Also, with fall and spring Chinook, multiple rivers will need to be represented. Finally, especially for fall Chinook, more attention should be given to the bays, as explained below.

According to Hendrix et al. (2014): "In the San Francisco estuary, outmigrating Chinook salmon do not use the bay habitat for feeding and arrive in the Gulf of the Farallones with relatively low lipid content (MacFarlane and Norton 2002)." MacFarlane and Norton (2002) reported that the juvenile fall Chinook that they sampled grew slowly as they passed through the bays, and then grew rapidly once they reached the Gulf of the Farallones. Unfortunately, they over-stated their results, for example in the following language in their abstract:

> Data suggest that chinook salmon from California's Central Valley have evolved a strong ecological propensity for an ocean-type life history. But unlike populations in the Pacific Northwest, they show little estuarine[1] dependency and proceed to the ocean to benefit from the upwelling-driven, biologically productive coastal waters.

The problem is that their sampling did not begin until April 30, by which time migrating fish were over 80 mm in length (Figure 3 in MacFarlane and Norton 2002), and their sampling was in deep water, whereas the literature about juvenile rearing in estuaries refers to smaller fish around the margins of the estuary. As summarized in Williams (2012):

> Based on studies of other estuaries, Chinook that migrate to the estuary as fry tend to rear there for some time, while Chinook that rear to fingerling size (~ 60+ mm) or larger somewhere upstream tend to pass through the estuary more rapidly (Healey 1991; Burke 2004). Small Chinook occupy mainly shallow water around the margins of the estuary, often moving up into

[1] Note that MacFarlane and North (2002) defined the estuary in terms of salinity, which excludes the Delta.

> tidal marsh channels on the flood tide, and retreating back to subtidal areas late on the ebb tide (Levy and Northcote 1982; Lott 2004). The juveniles tend to move into deeper water and down the estuary as they grow (Healey 1980; 1991).

In other words, the McFarlane and Norton (2002) results are not inconsistent with other reports in the literature, and there is evidence that the bays are indeed important habitat for Central Valley fall Chinook. Based on otolith microchemisty, Miller et al. (2010) reported that 20% of a sample of Central Valley fall Chinook taken in the ocean fishery had entered brackish water (i.e., the bays) by the time they reached 55 mm. These would have been naturally produced fish, since very few hatchery fish are released at that size, so assuming that a substantial proportion of their sample were hatchery fish, the percentage of naturally produced fish in the sample that reared in the bays must have been larger than 20%, likely much larger. Whether the sample was an outlier or reasonably representative is an important question that can easily be answered, if managers were willing to allocate money to appropriate studies.

It may also be necessary to include more categories of juveniles than fry and smolt for applying the model to spring and fall Chinook. Unfortunately, there is not good information on which juvenile life history patterns produce significant numbers of adult fish, although this also could be determined by analyzing the otoliths of naturally produced adults.

Finally, density-dependent mortality in the Delta and bays probably is more important for fall-run, especially those migrating when tens of millions of hatchery fish are released.

**ToR 4):**
*Is there evidence that the developed life cycle models can be placed within a relevant decision-making framework? What are the key strengths? What is the model telling us more broadly?*

Given that the Version 1.1 is a work in progress, and work on Version 2 is underway, I think the answer probably will be yes, but only if the model is used thoughtfully by people who understand both the model and its limitations, and also understand the biology of the species and the limitations of the existing data on the species. Put differently, the model may well be more useful for generating questions and identifying data gaps than producing answers. I suspect that some managers and many stakeholders want the model to be a source of clear answers incorporating the best available science, but given the state of the science this expectation is not realistic.

## Conclusions and Recommendations:

*Conclusions:*

Version 1.1 of the LCM is a work in progress that was presented to the panel during the workshop, and the only documentation of many aspects of the model that we have is PowerPoint presentations. We were told that Version 2 is in the works, and presumably this will be the version used for the Biological Opinion. As a result, the subject of the review is a bit of a moving target. With that caveat, I think that enormous progress on developing a useful life cycle model has been accomplished, but much remains to be done, and I am not confident that it can be done on the schedule that managers would like. This is not a criticism of the model or the modelers, but rather a statement of how difficult it is to develop such a model. Again, I was very impressed at the progress that has been made; before the workshop, I was doubtful that developing a useful model was feasible.

Does the model represent the best available science? Because the model is still a work in progress, my assessment must be hedged. Certainly, the model being developed with state-of-the-art methods, and assuming that Version 2 deals with process error as well as observation error, it will represent the best available modeling methods. Assuming that Version 2 incorporates the first three recommendations below, I think it will embody the best available science.

I also want to emphasize that the form and usefulness of the model are seriously constrained by the quality of the data that are available. My impression is that study of Central Valley Chinook has for many years been overly focused on the immediate effects of the state and federal facilities, particularly the diversion facilities in the Delta, mainly using tagged hatchery fish. In consequence, there has been inadequate attention to basic biology and the life histories and survival of naturally produced fish, despite the power of otolith analyses for the purpose (e.g., Barnett-Johnson et al. 2008: Miller et al. 2010; Sturrock et al. 2015), and the emphasis on naturally produced fish in the Central Valley Project Improvement Act. In other words, the chicken of short-sighted research priorities has come home to roost.

*Recommendations:*

1. Divide the representation of the river in the model into two sections, at Red Bluff.

2. Account for the effects of hatchery fish on the productivity of Chinook populations.

3. Develop Bayesian Network models for the habitat capacity of the river, using the opinions of field biologists as well as other information to populate the conditional probability tables. Use this in place of the depth, velocity, roughness method. As an alternative, simply use the opinion of field biologists who have spent time in the river observing habitat use by juvenile Chinook.

4. Be cautious about assuming density-dependent migration, or ignoring density-dependent mortality.

5. Reconsider the treatment of the bays in the model, particularly for fall Chinook.

6. Promote more research into the juvenile life histories of naturally produced juvenile Chinook, and on the effects of interactions with hatchery fish on naturally produced Chinook.

7. Consider using synthetic hydrology to develop input for CALSIM that reflects different climate change scenarios, and to check the influence of details of the historical record on model results.

**The Summary Report and the Review Process:**

I found the summary report useful for jogging my memory, but I think that the discussion at the panel workshop moved too quickly and was too disjointed for the note-takers to follow, so that the report does not represent an accurate account of the workshop. I have tried to produce reports of meetings somewhat like this in the past, and found it impossible to do without a recording of the meeting.

I think the panel had a good range of expertise that covered the issues that came up for discussion, and the NMFS presenters were well prepared. However, it would have been helpful if the panel had been given more information on what to expect at the workshop, for example in a short document describing briefly how the work had progressed since 2014.

Apart from informal discussion during our time in Santa Cruz and participation in the workshop, the panel did not engage in any work as a panel.

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Mara S. Zimmerman, Clayton Kinsel, Eric Beamer, Edward J. Connor & David E. Pflug 2015 Abundance, Survival, and Life History Strategies of Juvenile Chinook Salmon in the Skagit River, Washington, Transactions of the American Fisheries Society, 144:3, 627-641.

**Appendix 1:**

Materials Provided for Review

Hendrix, N., Criss, A., Danner, E. Greene, C.M., Imaki, H., Pike, A., and S.T. Lindley, 2014. Life Cycle Modeling Framework for Sacramento River Winter-run Chinook Salmon, NOAA-TM-NMFS-SWFSC-530. (26 pages).

Rose, K., Anderson, J., McClure, M. and G. Ruggerone. 2011. Salmonid Integrated Life Cycle Models Workshop: Report of the Independent Workshop Panel. Organized by the Delta Science Panel. (28 pages).

## Appendix 2:

# Statement of Work

### External Independent Peer Review by the Center for Independent Experts

### Central Valley Chinook Life Cycle Model Panel Review

**Scope of Work and CIE Process:** The National Marine Fisheries Service's (NMFS) Office of Science and Technology coordinates and manages a contract providing external expertise through the Center for Independent Experts (CIE) to conduct independent peer reviews of NMFS scientific projects. The Statement of Work (SoW) described herein was established by the NMFS Project Contact and Contracting Officer's Technical Representative (COTR), and reviewed by CIE for compliance with their policy for providing independent expertise that can provide impartial and independent peer review without conflicts of interest. CIE reviewers are selected by the CIE Steering Committee and CIE Coordination Team to conduct the independent peer review of NMFS science in compliance the predetermined Terms of Reference (ToRs) of the peer review. Each CIE reviewer is contracted to deliver an independent peer review report to be approved by the CIE Steering Committee and the report is to be formatted with content requirements as specified in **Annex 1**. This SoW describes the work tasks and deliverables of the CIE reviewer for conducting an independent peer review of the following NMFS project. Further information on the CIE process can be obtained from www.ciereviews.org.

**Project Description:**

In April 2011, at the request of NMFS, the Delta Science Panel (DSP) convened an independent review panel to provide recommendations on how the agency should proceed with incorporating life cycle modeling of Chinook salmon into the ongoing analyses related to the Operations Criteria and Plan (OCAP), Biological Opinion (BiOp), and Reasonable Prudent Alternatives (RPA). The review panel reviewed existing models and considered four questions on model development. In June 2011, the review panel produced a report, *Salmonid Integrated Life Cycle Models Workshop: Report of the Independent Workshop Panel,* detailing their recommendations. One recommendation was that NMFS create a salmonid life cycle model tailored expressly for their purposes.

The Southwest Fisheries Science Center (SWFSC) has developed a new salmonid life cycle modeling framework which will be used to analyze water management scenarios on fish survival in the current development of the Biological Assessment (BA) for the Bay-Delta Conservation Plan. SWFSC is now requesting that a similar panel review the newly developed life cycle modeling framework. An independent panel review of the model will add credibility in its use in the BA scheduled to be completed in March 2016.

The Terms of Reference (ToRs) of the peer review are attached in **Annex 2**. The tentative agenda of the panel review meeting is attached in **Annex 3**.

**Requirements for CIE Reviewers:** Three CIE reviewers shall conduct an impartial and independent peer review in accordance with the SoW and ToRs herein. CIE reviewers should have expertise in water, habitat and fisheries management and coupled physical-biological models of freshwater or estuarine fish populations; landscape ecology; and knowledge of Pacific salmonid life history and ecology.

Each CIE reviewer's duties shall not exceed a maximum of 14 days to complete all work tasks of the peer review described herein.

**Location of Peer Review:** Each CIE reviewer shall conduct an independent peer review during the panel review meeting scheduled in **Santa Cruz, CA at the Southwest Fisheries Science Center's Fisheries Ecology Division** during November 5-6, 2015.

**Statement of Tasks:** Each CIE reviewers shall complete the following tasks in accordance with the SoW and Schedule of Milestones and Deliverables herein.

Prior to the Peer Review: Upon completion of the CIE reviewer selection by the CIE Steering Committee, the CIE shall provide the CIE reviewer information (full name, title, affiliation, country, address, email) to the COTR, who forwards this information to the NMFS Project Contact no later the date specified in the Schedule of Milestones and Deliverables. The CIE is responsible for providing the SoW and ToRs to the CIE reviewers. The NMFS Project Contact is responsible for providing the CIE reviewers with the background documents, reports, foreign national security clearance, and other information concerning pertinent meeting arrangements. The NMFS Project Contact is also responsible for providing the Chair a copy of the SoW in advance of the panel review meeting. Any changes to the SoW or ToRs must be made through the COTR prior to the commencement of the peer review.

Foreign National Security Clearance: When CIE reviewers participate during a panel review meeting at a government facility, the NMFS Project Contact is responsible for obtaining the Foreign National Security Clearance approval for CIE reviewers who are non-US citizens. For this reason, the CIE reviewers shall provide requested information (e.g., first and last name, contact information, gender, birth date, passport number, country of passport, travel dates, country of citizenship, country of current residence, and home country) to the NMFS Project Contact for the purpose of their security clearance, and this information shall be submitted at least 30 days before the peer review in accordance with the NOAA Deemed Export Technology Control Program NAO 207-12 regulations available at the Deemed Exports NAO website:
http://deemedexports.noaa.gov/
http://deemedexports.noaa.gov/compliance_access_control_procedures/noaa-foreign-national-registration-system.html

Pre-review Background Documents: Two weeks before the peer review, the NMFS Project Contact will send (by electronic mail or make available at an FTP site) to the CIE reviewers the necessary background information and reports for the peer review. In the case where the documents need to be mailed, the NMFS Project Contact will consult with the CIE Lead

Coordinator on where to send documents. CIE reviewers are responsible only for the pre-review documents that are delivered to the reviewer in accordance to the SoW scheduled deadlines specified herein. The CIE reviewers shall read all documents in preparation for the peer review.

Hendrix, N., Criss, A., Danner, E. Greene, C.M., Imaki, H., Pike, A., and S.T. Lindley, 2014. Life Cycle Modeling Framework for Sacramento River Winter-run Chinook Salmon, NOAA-TM-NMFS-SWFSC-530. (26 pages)

Rose, K., Anderson, J., McClure, M. and G. Ruggerone. 2011. Salmonid Integrated Life Cycle Models Workshop: Report of the Independent Workshop Panel. Organized by the Delta Science Panel. (28 pages)

Panel Review Meeting: Each CIE reviewer shall conduct the independent peer review in accordance with the SoW and ToRs, and shall not serve in any other role unless specified herein. **Modifications to the SoW and ToRs cannot be made during the peer review, and any SoW or ToRs modifications prior to the peer review shall be approved by the COTR and CIE Lead Coordinator.** Each CIE reviewer shall actively participate in a professional and respectful manner as a member of the meeting review panel, and their peer review tasks shall be focused on the ToRs as specified herein. The NMFS Project Contact is responsible for any facility arrangements (e.g., conference room for panel review meetings or teleconference arrangements). The NMFS Project Contact is responsible for ensuring that the Chair understands the contractual role of the CIE reviewers as specified herein. The CIE Lead Coordinator can contact the Project Contact to confirm any peer review arrangements, including the meeting facility arrangements.

The role of the panel is to review the framework for the Central Valley winter-run Chinook life cycle model developed by NOAA Fisheries SWFSC FED to determine whether NOAA Fisheries has fulfilled the recommendations given by Rose et al in the report, Salmonid Integrated Life Cycle Models Workshop: Report of the Independent Workshop Panel. The panel will appoint a chair and will use the Terms of Reference outlined in this document to guide their review. The chair will run the meeting and lead the development of a summary report on the second day of the review.

The specific responsibilities of the panel are to:
1. Review the technical documents listed above prior to the panel review.
2. Listen to presentations by project scientists describing the model framework.
3. Develop a summary report detailing whether NMFS has met the recommendations outlined in the report Salmonid Integrated Life Cycle Models Workshop: Report of the Independent Workshop Panel developed by Rose et al.

Contract Deliverables - Independent CIE Peer Review Reports: Each CIE reviewer shall complete an independent peer review report in accordance with the SoW. Each CIE reviewer shall complete the independent peer review according to required format and content as described in Annex 1. Each CIE reviewer shall complete the independent peer review addressing each ToR as described in Annex 2.

<u>Other Tasks – Contribution to Summary Report</u>: Each CIE reviewer may assist the Chair of the panel review meeting with contributions to the Summary Report, based on the terms of reference of the review. Each CIE reviewer is not required to reach a consensus, and should provide a brief summary of the reviewer's views on the summary of findings and conclusions reached by the review panel in accordance with the ToRs.

**Specific Tasks for CIE Reviewers:** The following chronological list of tasks shall be completed by each CIE reviewer in a timely manner as specified in the **Schedule of Milestones and Deliverables**.

1) Conduct necessary pre-review preparations, including the review of background material and reports provided by the NMFS Project Contact in advance of the peer review.
**2)** Participate during the panel review meeting in Santa Cruz, CA from 5-6 November 2015.
3) Conduct an independent peer review in accordance with the ToRs (**Annex 2**).
4) No later than 20 November 2015, each CIE reviewer shall submit an independent peer review report addressed to the "Center for Independent Experts," and sent to Dr. Manoj Shivlani, CIE Lead Coordinator, via email to *mshivlani@ntvifederal.com*, and Dr. David Die, the CIE Regional Coordinator, via email to *ddie@rsmas.miami.edu*. Each CIE report shall be written using the format and content requirements specified in Annex 1, and address each ToR in **Annex 2**.

**Schedule of Milestones and Deliverables:** CIE shall complete the tasks and deliverables described in this SoW in accordance with the following schedule.

| | |
|---|---|
| *October 9, 2015* | CIE sends reviewer contact information to the COTR, who then sends this to the NMFS Project Contact |
| *October 22, 2015* | NMFS Project Contact sends the CIE Reviewers the pre-review documents |
| ***November 5-6 2015*** | Each reviewer participates and conducts an independent peer review during the panel review meeting |
| *November 20, 2015* | CIE reviewers submit draft CIE independent peer review reports to the CIE Lead Coordinator and CIE Regional Coordinator |
| *December 4, 2015* | CIE submits CIE independent peer review reports to the COTR |
| *December 8, 2015* | The COTR distributes the final CIE reports to the NMFS Project Contact and regional Center Director |

**Modifications to the Statement of Work:** This 'Time and Materials' task order may require an update or modification due to possible changes to the terms of reference or schedule of milestones resulting from the fishery management decision process of the NOAA Leadership, Fishery Management Council, and Council's SSC advisory committee. A request to modify this SoW must be approved by the Contracting Officer at least 15 working days prior to making any permanent changes. The Contracting Officer will notify the COTR within 10 working days after receipt of all required information of the decision on changes. The COTR can approve changes to the milestone dates, list of pre-review documents, and ToRs within the SoW as long as the role and ability of the CIE reviewers to complete the deliverable in accordance with the SoW is not adversely impacted. The SoW and ToRs shall not be changed once the peer review has begun.

**Acceptance of Deliverables:** Upon review and acceptance of the CIE independent peer review reports by the CIE Lead Coordinator, Regional Coordinator, and Steering Committee, these reports shall be sent to the COTR for final approval as contract deliverables based on compliance with the SoW and ToRs. As specified in the Schedule of Milestones and Deliverables, the CIE shall send via e-mail the contract deliverables (CIE independent peer review reports) to the COTR (William Michaels, via William.Michaels@noaa.gov).

**Applicable Performance Standards:** The contract is successfully completed when the COTR provides final approval of the contract deliverables. The acceptance of the contract deliverables shall be based on three performance standards:
(1) The CIE report shall completed with the format and content in accordance with **Annex 1**,
(2) The CIE report shall address each ToR as specified in **Annex 2**,
(3) The CIE reports shall be delivered in a timely manner as specified in the schedule of milestones and deliverables.

**Distribution of Approved Deliverables:** Upon acceptance by the COTR, the CIE Lead Coordinator shall send via e-mail the final CIE reports in *.PDF format to the COTR. The COTR will distribute the CIE reports to the NMFS Project Contact and Center Director.

**Support Personnel:**

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**Annex 1: Format and Contents of CIE Independent Peer Review Report**

1. The CIE independent report shall be prefaced with an Executive Summary providing a concise summary of the findings and recommendations, and specify whether the science reviewed is the best scientific information available.

2. The main body of the reviewer report shall consist of a Background, Description of the Individual Reviewer's Role in the Review Activities, Summary of Findings for each ToR in which the weaknesses and strengths are described, and Conclusions and Recommendations in accordance with the ToRs.

   a. Reviewers should describe in their own words the review activities completed during the panel review meeting, including providing a brief summary of findings, of the science, conclusions, and recommendations.

   b. Reviewers should discuss their independent views on each ToR even if these were consistent with those of other panelists, and especially where there were divergent views.

   c. Reviewers should elaborate on any points raised in the Summary Report that they feel might require further clarification.

   d. Reviewers shall provide a critique of the NMFS review process, including suggestions for improvements of both process and products.

   e. The CIE independent report shall be a stand-alone document for others to understand the weaknesses and strengths of the science reviewed, regardless of whether or not they read the summary report. The CIE independent report shall be an independent peer review of each ToRs, and shall not simply repeat the contents of the summary report.

3. The reviewer report shall include the following appendices:

   Appendix 1: Bibliography of materials provided for review
   Appendix 2: A copy of the CIE Statement of Work
   Appendix 3: Panel Membership or other pertinent information from the panel review meeting.

## Annex 2: Terms of Reference for the Peer Review

## Central Valley Chinook Life Cycle Model Panel Review

1) Is the model useful for informing NMFS of the effects of water operations and prescribed RPA actions on salmonids at various life stages and at the population level?
   a) What are the strengths and weaknesses of the model?
   b) Are key parameters and performance measures captured in the model? If not, what other parameters and performance measures should be included?
   c) Can the model be applied to address the multiple timescales associated with RPA decisions and operations?
   d) What are the technical constraints to the implementation of the model and the feasibility to address them (e.g., transparency of the model, data sets availability, model parameter uncertainties and sensitivities, etc.)?

2) Has NMFS effectively linked multiple specific models to represent the whole life cycle to inform NMFS in determining the effects of water operations and prescribed RPA actions on salmonids at the population level?

3) Is the model framework suitable for winter-run, spring-run, and fall-run and can the framework be adapted for other species of Pacific salmonids?

4) Can the model fit into a decision-making framework for using life cycle models (at appropriate temporal and spatial scales) to adapt water operations and prescribed RPA actions on individual and multiple species?

## Annex 3: Tentative Agenda

**Central Valley Chinook Life Cycle Model Panel Review**
Southwest Fisheries Science Center, 110 Shaffer Road, Santa Cruz, CA 95062
November 5-6, 2015, 8:30 am – 5:00 pm

First day

| | |
|---|---|
| 8:30 am Arrival and coffee | |
| 9:00 am Welcome and introductions | Steve Lindley |
| 9:10 am Legal and Regulatory Context | Rea, McClain, or Yip (NMFS-CVO office) |
| 9:30 am Project Overview | Steve Lindley |
| 9:45 am Winter-run Life Cycle Model Framework Part 1 | Noble Hendrix |
| 10:45 am Break | |
| 11:00 am Winter-run Life Cycle Model Framework Part 2 | Noble Hendrix |
| 12:00 pm Lunch | |
| 1:15 pm Habitat Capacity | Correigh Greene |
| 1:45 pm Enhanced Particle Tracking Model | Steve Lindley |
| 2:15 pm Break | |
| 2:30 pm Panel and Presenter Discussion | |
| 4:30 pm Public Comment and Concluding Remarks | Steve Lindley |
| 5:00 pm Adjourn | |

Second Day

9:00 Panel Report Preparation

Point of contact for reviewer security & check-in

Anne Criss, Assistant to the Director
Fisheries Ecology Division
Southwest Fisheries Science Center

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## Appendix 3. The Panel

The panel consisted of Jamie Gibson, Contractor, Wolfville, Nova Scotia; David Hankin, Professor Emeritus, Department of Fisheries, College of Natural Resources and Sciences, Humboldt State University, California; and John Williams, Consultant, Petrolia, California